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Request for grant of a patent

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1.	Your reference	Jg-2480
2.	Patent application number *(The Patent Office will fill in this part)*	**9913769.7**
3.	Full name, address and postcode of the or of each applicant *(underline all surnames)*	SEOS Displays Limited, Marchants Way, Burgess Hill West Sussex, RH15 8QY United Kingdom
	Patents ADP number *(if you know it)*	6917256001
	If the applicant is a corporate body, give the country/state of its incorporation	United Kingdom
4.	Title of the invention	VISUAL DISPLAY SYSTEMS FOR CAR AND TRUCK SIMULATORS.
5.	Name of your agent *(if you have one)*	Graham Jones & Company
	"Address for service" in the United Kingdom to which all correspondence should be sent *(including the postcode)*	77 Beaconsfield Road Blackheath London SE3 7LG
	Patents ADP number *(if you know it)*	2097001

		Country	Priority application number *(if you know it)*	Date of filing *(day / month / year)*
6.	If you are declaring priority from one or more earlier patent applications, give the country and the date of filing of the or of each of these earlier applications and *(if you know it)* the or each application number			

		Number of earlier application	Date of filing *(day / month / year)*
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8.	Is a statement of inventorship and of right to grant of a patent required in support of this request? *(Answer 'Yes' if:* *a) any applicant named in part 3 is not an inventor, or* *b) there is an inventor who is not named as an applicant, or* *c) any named applicant is a corporate body.* *See note (d))*	Yes

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Statement of inventorship and right to grant of a patent *(Patents Form 7/77)*	
Request for preliminary examination and search *(Patents Form 9/77)*	
Request for substantive examination *(Patents Form 10/77)*	
Any other documents *(please specify)*	

11. I/We request the grant of a patent on the basis of this application.

Signature Graham Jones Date 14/6/1999

12. Name and daytime telephone number of person to contact in the United Kingdom Mr G.H. Jones 0181 858 4039

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Statement of inventorship and of right to grant of a patent

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1. Your reference — Jg-2480

2. Patent application number *(if you know it)*

3. Full name of the or of each applicant — SEOS Displays Limited

4. Title of the invention — VISUAL DISPLAY SYSTEMS FOR CAR AND TRUCK SIMULATORS

5. State how the applicant*(s)* derived the right from the inventor*(s)* to be granted a patent — By virtue of agreement and conditions of employment

6. How many, if any, additional Patents Forms 7/77 are attached to this form? *(see note (c))* — One

7. I/We believe that the person*(s)* named over the page *(and on any extra copies of this form)* is/are the inventor*(s)* of the invention which the above patent application relates to.

Signature Graham Jones & Company Date 14/6/1999

8. Name and daytime telephone number of person to contact in the United Kingdom — Mr G.H. Jones 0181 858 4039

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Enter the full names, addresses and postcodes of the inventors in the boxes and underline the surnames

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United Kingdom.

Patents ADP number *(if you know it)*:

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Reminder

Have you signed the form?

VISUAL DISPLAY SYSTEMS FOR CAR AND TRUCK SIMULATORS

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Abstract
Driving simulation places unique demands on the visual system. To assume that standards satisfactory for flight simulation can be simply transferred to driving simulation will generally result in too high a cost and inappropriate performance. Indeed, some aspects of driving simulation place greater demands on the display than does civil flight simulation! Key factors to be considered when designing an Out-the-Window display system for trucks are: cost vs performance; resolution; luminance & contrast, scene continuity; image distance and its variability. Currently a number of possible solutions exist, each with their respective advantages and drawbacks. The user community rather than the simulator builders could perhaps better answer some of these questions, but a new class of display may enable more of the advantages to be available at one time.

Driving Simulator Display Requirements
The development of flight simulator Out-the-Window (OTW) displays has provided us with a technological baseline from which we could build displays for truck and car simulators. However, the cost of commercial flight simulator displays has in the past been prohibitive for all but the most specialised high-end driving simulators. Contradicting this aspect, however, is that the requirements for simulation of environments and situations for ground vehicles can be more demanding, not less! Competition and the development of high performance and low cost display devices for much larger markets than simulation have combined to warrant the re-visiting of this dilemma.

The use of professional (as opposed to entertainment) driving simulators may be categorised in a number of ways but, to try to draw conclusions as to the performance needs and cost justifications, two simple categories could be:

Training: The objective is to impart some new skill on the subject. Examples could be for basic vehicle operation, conversion between vehicle types, emergency services (e.g., police pursuit) and post-injury rehabilitation.

Research: Rather than receiving training, the subject is instead part of an experiment or study, which could be in vehicle design (performance and aesthetics), human factors studies (effects of drugs, ageing etc.) and even road planning, for example sign & signal design and placement and road markings.

Such categorisation has long existed in flight simulation and it would appear to hold up well also for ground vehicles.

Generally, cost justification is quite different between training and research. For training, the balance of justification on cost-effectiveness alone is very difficult, as today all training is performed successfully on the real vehicles, whilst the cost of a simulator of sufficient fidelity usually far exceeds the cost of the vehicle it simulates. The exception here, which itself probably represents the most immediate opportunity for viable training simulation, is

where the end-user is not the general public, but rather a "specialist user" of some sort. Examples could be:

- Police, Fire or other emergency services.
- Military vehicles, from tanks to motorcycles
- Dangerous goods handling: cranes, earth-movers etc.

In such cases;

a) the vehicle can be expensive
b) often training may be unacceptable in the real vehicle
c) simulation is valued for the "normal" reasons that it does excel in: weather variation, dangerous situations, environmental considerations etc.

Finally, with regard to training, as yet there are no regulatory authorities insisting upon simulation being part of training curricula. Should this happen, the simulation market for ground vehicles perhaps most likely to start with trucks and buses, could grow rapidly.

Use of driving simulation for research has probably dominated the development of simulators to date, examples being the Iowa Driving Simulator and the Daimler-Benz Driving Simulator [1]. Many references exist for research applications of simulators, for example through examination of any recent DSC proceedings. Justification for such devices is complex and depends on the objectives of the research. However, even here the pressure for low cost solutions is great.

Generally, therefore, the following discussion addresses "specialist training" and research applications as they relate to the visual OTW display. Solutions developed may be expected to migrate downwards toward general driver training as they become standardised and benefit from ever-continuing developments in low-cost display components and related technologies, such as PC-based Image Generators.

Specification of the display

As a collection of requirements for the main OTW display for trucks and cars, a typical procurement specification could be:

PARAMETER	SPEC	COMMENT
Field of View	180° to 200° Horizontal, 40° Vertical	Not including rear-view. Often biased to driver's side
Resolution	6 to 8 arc-min/optical line pair (arc-min/olp)	768 to 1024 lines
Luminance	>6 Foot-Lamberts	
Contrast	>15:1	
Blend uniformity	<2%	Not often specified as segmented systems assumed.
Number of channels	3 or 5	
Motion compatibility	Normal flight simulation standards or greater	Often off-motion
Mass	2500kg	Requiring large motion base
Cost	???	Low.

Table 1: Typical Requirement Specification for a Truck or Car Simulator Display

A common theme here is the quest for as large a field-of-view as possible, with as high a resolution as possible, for the lowest possible cost! With regard to resolution, there seems to be a wide range of opinions as to what is acceptable. One important factor is the visibility of a simulated sign, which with a display resolution of 6 arc-min/olp, would not be legible until it is much closer than the real sign would be. However to specify, say, 3 arc-min/olp everywhere would be cost-prohibitive, both in the display and the Image Generator. One pragmatic solution taken has been to artificially magnify the size of signs, such that they are legible at the appropriate distances, but detractors object to the unnatural sign appearance. Progressively reducing the sign size to the correct value as it comes into range could help, but this can present a dynamic artefact that detracts from realism. Target projectors, as used in military flight simulators to present enemy aircraft, could be used to display signs by overlaying or cutting into the main scene. However, the cost for such a solution is likely to be prohibitive and, unless the dynamic correlation is perfect, the signs would give the sensation of floating in the simulated world.

Current OTW Display Solutions

It is probably true to say that, when it comes to OTW display systems, training simulator builders have fitted what they could afford, rather than what they would like. In doing so, the important trade-offs must be related to the ability to complete the training objectives with the display selected. In the field of military flight simulation there has been a great deal of analysis of this type, examples being the Vis-Eval programme [2], which evaluated a wide range of display architectures for their ability to "tick boxes" in training programmes, and the AGARD report on visual systems [3].

Truck and car simulators have been built with a wide range of OTW display systems. For training usage, they have in the main been confined to four basic types: Direct-view monitors, front-projected real-image, rear-projected real-image and (rear) projected tilted mirror collimators. Head-Mounted Displays (HMDs) have found application recently, although mainly in a research application environment.

Direct-view monitors:

Here, graphics monitors are fitted directly on to the simulator cab, around the driver. Whilst this provides the most cost-effective and compact system (particularly if large flat-panel displays were to replace CRT monitors), the extremely short accommodation (or viewing) distance and large gaps between viewable channels do not really result in a high-fidelity display. Such systems certainly have value where these aspects do not impact on the training requirement and the relatively restrictive cab environment fidelity can be tolerated. It is assumed from hereon, however, that these factors matter; we require cab fidelity, acceptable accommodation and as continuous a visual field as possible.

Front-Projected Real-Image Systems (PRODAS):

One approach that can be taken to provide a wrap-around display is to place a curved screen around the simulator cab and front-project onto it, using Cathode Ray Tube (CRT) projectors. The SEOS PRODAS system is an example of such a display, often used in single-seat flight simulators. CRT projectors form their images from what is essentially a continuous scanning process, which gives the technology the distinguishing characteristic of "infinite address-ability". What this amounts to in practice is that, through introduction of terms in the electronic scanning subsystem of the projector, the projected image formed can be distorted in a continuous fashion. This ability is particularly useful when projecting onto

curved screen surfaces [4] and has been a key factor in CRT projection remaining dominant in simulation displays for more than 20 years

In such systems, the projectors must be placed within the screen volume, effectively "sharing" the space with the rest of the simulator. Experience has found that this can be particularly difficult where the cab to be simulated is large and or there is a constrained room size. Figure 1 shows a sample SEOS PRODAS layout for a Sports Utility Vehicle simulator. The screen is a continuous cylinder (the "joins" are simply the supports for the screen) and the 8-inch electromagnetic PRODAS 818 projectors cross-fire above the axis of the driver's eye-point. One of the objectives of this layout is to use a vehicle cab with the absolute minimum modification to its structure, a frequently met requirement, as a wide range of vehicles are to be simulated over time

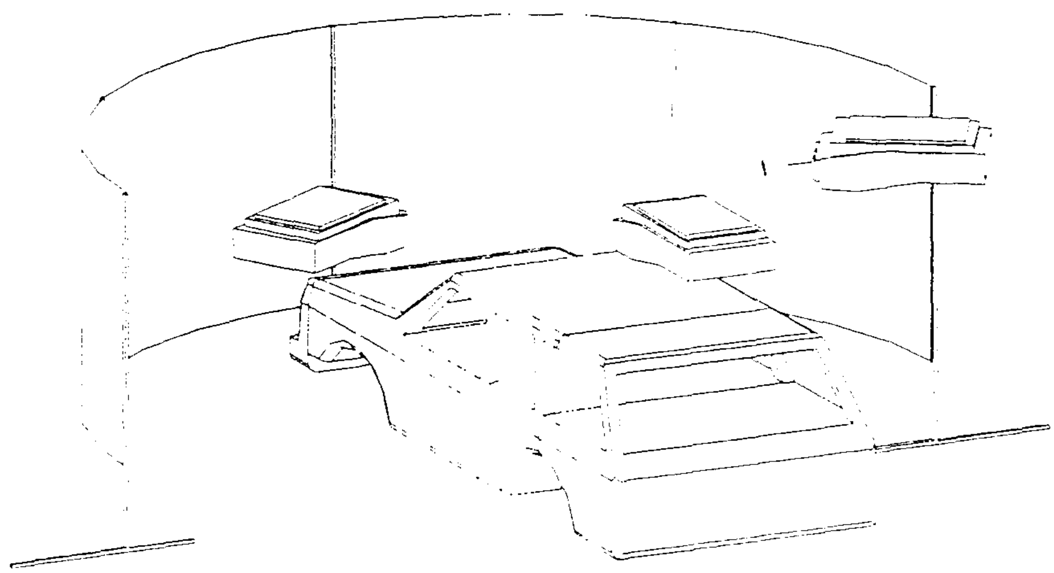

Figure 1: Sample front-projected SEOS PRODAS display for a Sports Utility Vehicle

Figure 2 illustrates the type of problem experienced in attempting such a layout, where the extremes of the cab occlude the projected light path to the screen. Here, we are "looking out from" the central lens of the left-hand projector, through to the screen onto which is superimposed an azimuth elevation grid. The top corner of the vehicle cab can be seen to shadow a region in the lower-right extremes of the image. In fact, this layout has been tuned to keep this region outside the visible field of the driver, but it could be seen that for a larger cab, the problem becomes more difficult as suggested in Figure 3.

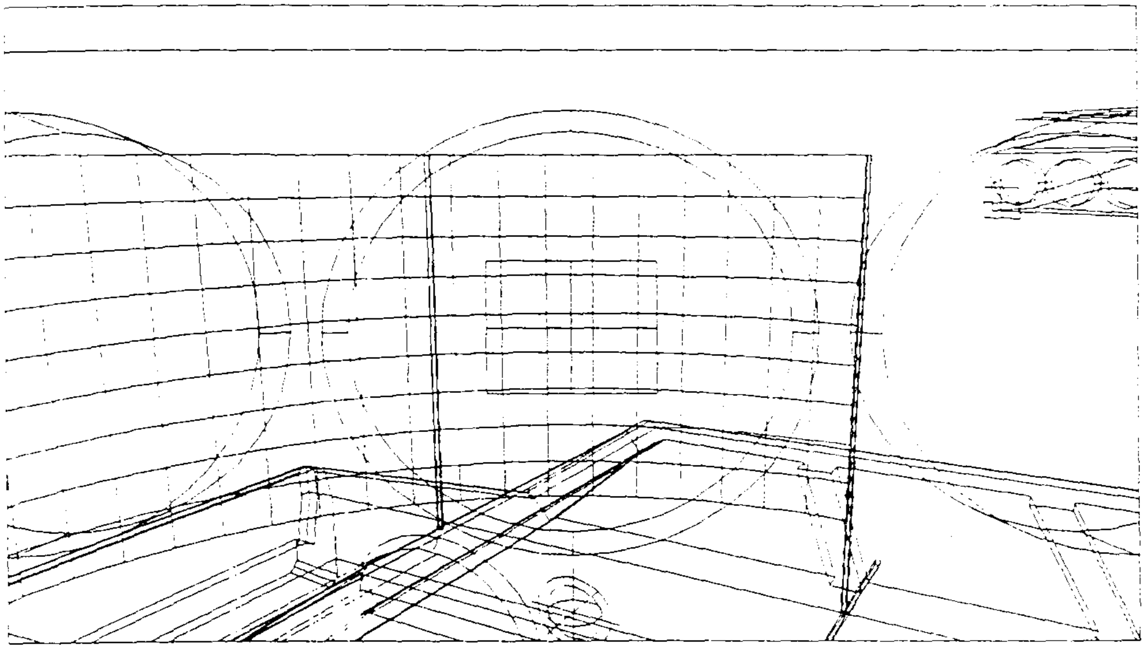

Figure 2: Field of view occlusion from vehicle cab.

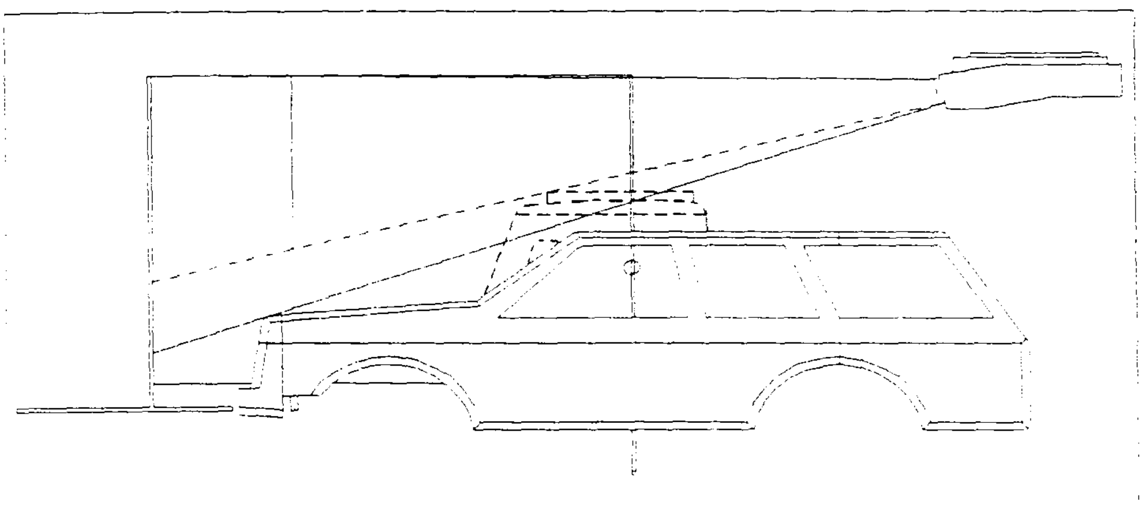

Figure 3: Dotted lines indicate extents of truck - More shadowing !!!!

Clearly, the projectors could be raised further to allow for larger cabs but, in doing so, projector geometric pre-distortion must be increased, projector structures become larger and, particularly for implementation on a motion system, significant cost starts to accumulate in the design realisation.

Many examples do exist, however, where the layout could be cost-effectively achieved. Where such solutions can be made to work, the benefits of front-projected CRT systems can be realised, these being:

- Continuous image presentation
- Mature projection technology, giving low risk and off-the-shelf availability
- High performance digital electronic blending

- Good dynamic image presentation.

However, the drawbacks include:

- designs tend to be cab-specific, requiring one-time design for each new simulator
- Often the required field of view must be compromised
- The cab may require modification to eliminate shadowing.

Front-Projected Liquid Crystal Display (LCD) Systems:

General comparisons between LCD and CRT technologies have previously been drawn in the field of flight simulation [4]. Since first becoming a potential candidate, LCD projection has held particular attraction, primarily due to the promise of reduced system maintenance, versatile lens options and the small physical size and weight for a given light output. Until recently, LCD front-projected displays were not deemed to be acceptable to realise simulation displays of adequate performance. Now, however, improved performance of such projectors, along with system-level enabling technologies of digital distortion correction and optical blending, have come together to offer a new capability option. This has already been recognised for flight simulation applications [5], but equally applies to the ground vehicle application.

Generally, the CRT front-projected layout example described can be replicated using LCD projectors. At system level, the increased light output now available can be traded to provide a higher image contrast performance (as long as image luminance is sufficient), and there is significant benefit from reduced maintenance overhead. However, the layout trade-offs are the same. There is a limit to how far off-axis the projectors can be placed, primarily through the wastage of displayable pixels.

Rear-projected flat screens (KESTREL):

Whilst front-projection suffers a basic drawback of layout difficulty due to shadowing problems, rear-projection appears to completely solve this problem. As depicted in figure 4, the projectors are arranged outside the enclosed volume of the display screen. Hence the simulator cab space is not shared by the projection devices, which themselves also radiate outwards from the system centre. Thus, no image occultation occurs and large fields of view can be relatively easily realised, even around the large awkwardly shaped truck and bus cabs. An added advantage is that, with the proper selection of screen material, the overall system contrast achievable can approach that of the basic projector, giving perhaps 25:1 compared to 15:1 for a comparable front-projection system.

However, rear-projection is not without its drawbacks. Firstly, multiple flat rear-projection screen sections are generally used to make up the total field of view in a piece-wise fashion. This results in a varying accommodation distance for the observer. Screen joins always represent a discontinuity, both because of this segmentation and, more importantly, from the effects of screen gain. Rear projection screens do not diffuse the light as evenly as matt-painted front-projection screens, but instead exhibit a preferential distribution along the axis of the incident light (Fig. 5). The on-axis rays, from the projector through to the eye, will be transmitted to the maximum nominal gain of the screen, which is typically around 1.5 [1]. The rays at the edges of the field of view are significantly away from this axis, and the gain lobe shape indicated in the figure can illustrate the fraction of light returning to the eye.

[1] The gain represents the luminance that would be achieved referenced to a 100 % matt white reflective surface, so a figure of 1.5 would result in a relative luminance of 150 %

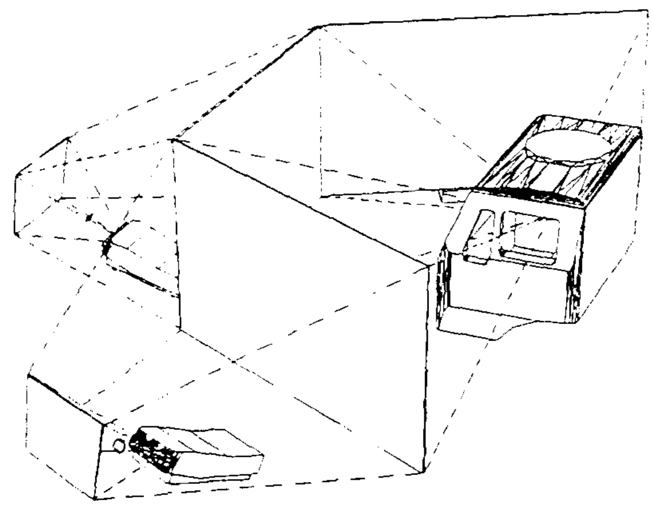

Figure 4: Rear-projected display for a truck simulator.

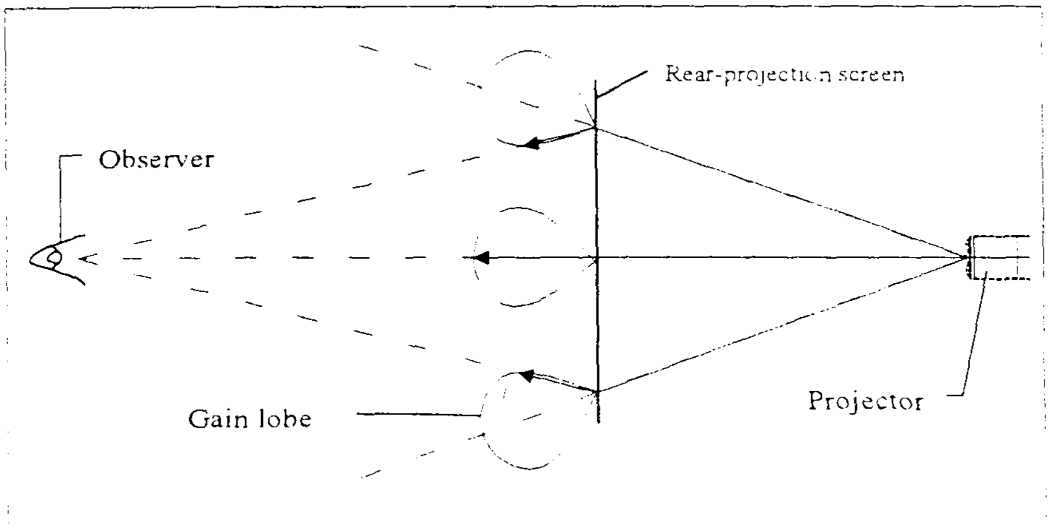

Figure 5: Rear-projection screen gain effect.

This manifests itself in the form of large image non-uniformity (Fig. 6). If a single projector was to illuminate a screen section covering 60° horizontal by 40° vertical, for example, the corner luminance would only provide around 25% of the centre luminance when viewed at the design eye-point. It is worth remembering, however, that the human eye can be surprisingly tolerant of such variations, and rear-projected systems of this type can be quite acceptable for simulation.

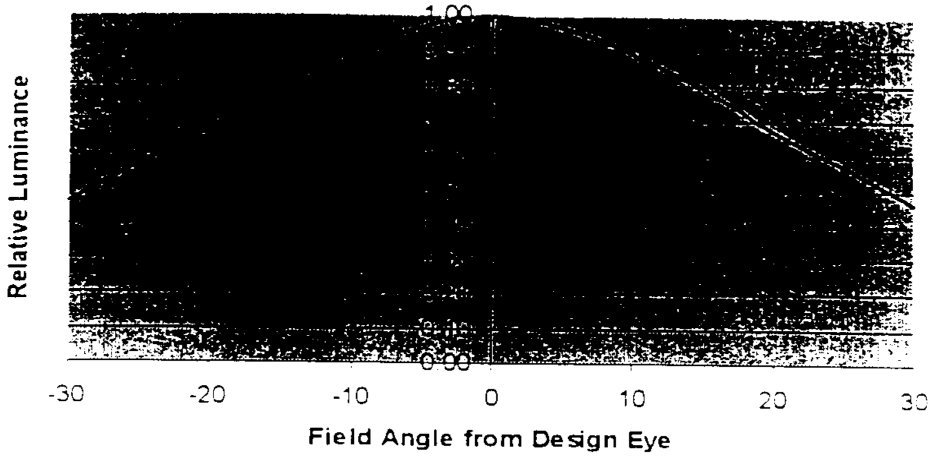

Figure 6: Luminance uniformity of rear-projected image.

Other points to note are:

- Use on a dynamic motion platform is difficult, owing to the large flat screen sections.
- Cylindrical screens could be used to provide a continuous image surface and be more motion-compatible. However, the gain lobe effects are further exaggerated horizontally, limiting individual channel fields of view.

Rear-projected systems are therefore very useful in providing large field-of-view OTW displays, but again have performance limitations that must be taken into account.

Collimated Projection (PANORAMA):

Tilted-mirror collimators have long been established as the mainstay of wide-bodied aircraft simulation but, until recently, have not been widely used for ground vehicles, largely because of cost. The primary components of such a display are (figure 7):

- Projection System, typically CRT-based, cross-firing above the simulator cab or cockpit.
- Rear-projection screen, typically spherical, placed above and in front of the cab. The projectors form an image on the outer surface of this screen.
- Collimating mirror, in front of the cab, wrapping round for a large horizontal field of view. The most cost-effective and common arrangement here is to stretch a polyester film coated in an aluminium reflective surface, over the edges of an evacuated mirror cell. The rear-projected image is viewed via this curved mirror.

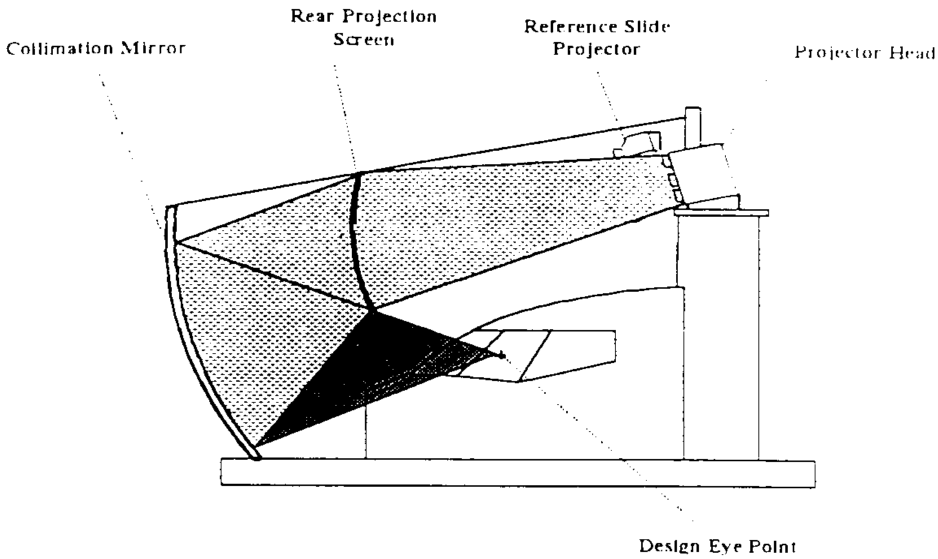

Figure 7: Tilted Mirror Collimation Flight Simulator Display (SEOS PANORAMA).

The relationship between the curvatures of the mirror and rear-projection screen is designed to set the image distance at a much greater value than that of the physical mirror radius (3m, typically). The image distance is usually set to a nominal value of 20m to 30m which significantly enhances the subjective realism of the scene. This also has great benefit in flight simulation, as the pilot and co-pilot now simultaneously perceive correct image geometry for distant objects. However, for a truck simulator, collimation may actually become a disadvantage. This is because the simulated environment often presents objects that are quite close to the driver, for example when adjacent to another vehicle. If displayed at an image distance of 20m, the relative size cues to the driver would be incorrect, especially with head movement.

The main cost drivers in this type of display are:

- The projection system – high-end CRT projectors typically, with high-quality digital blending.
- The rear-projection screen, which requires specialist tooling for the large spherical form-factors and precision coating technology.
- The projector support structures over the cab, which tends to be simulator-specific and "standard" designs cannot easily be used.
- To a lesser extent, the mirror cell. As this is a standard component, volume cost savings could apply.

Savings could be obtained by use of LCD or other fixed-matrix projectors, which would reduce the cost of supporting structures. Generally, however, other than for specific high-end or high-volume applications, it may be difficult to justify the cost of this class of display.

Head-Mounted Displays:

HMDs are finding application in a number of simulation research applications. One such example is as a part of the current Eureka CaRDS project [6], which is being led by Renault (Figure 8). The purpose here is to provide a near-100% synthetic environment through the use of fully immersive HMD visualisation. A generic driver cockpit would allow for re-configuration between vehicle types and the very low total load on the motion base would

enable simulation of any ground vehicles with a low-cost motion system. The HMD being developed will be of very high performance, to maximise user comfort and present a high fidelity rendition of the simulated environment, including that within the simulated vehicle. One point worth remembering is that an HMD allows an unrestricted field of regard: i.e., the driver would be able to look in any direction without limitation from the display device.

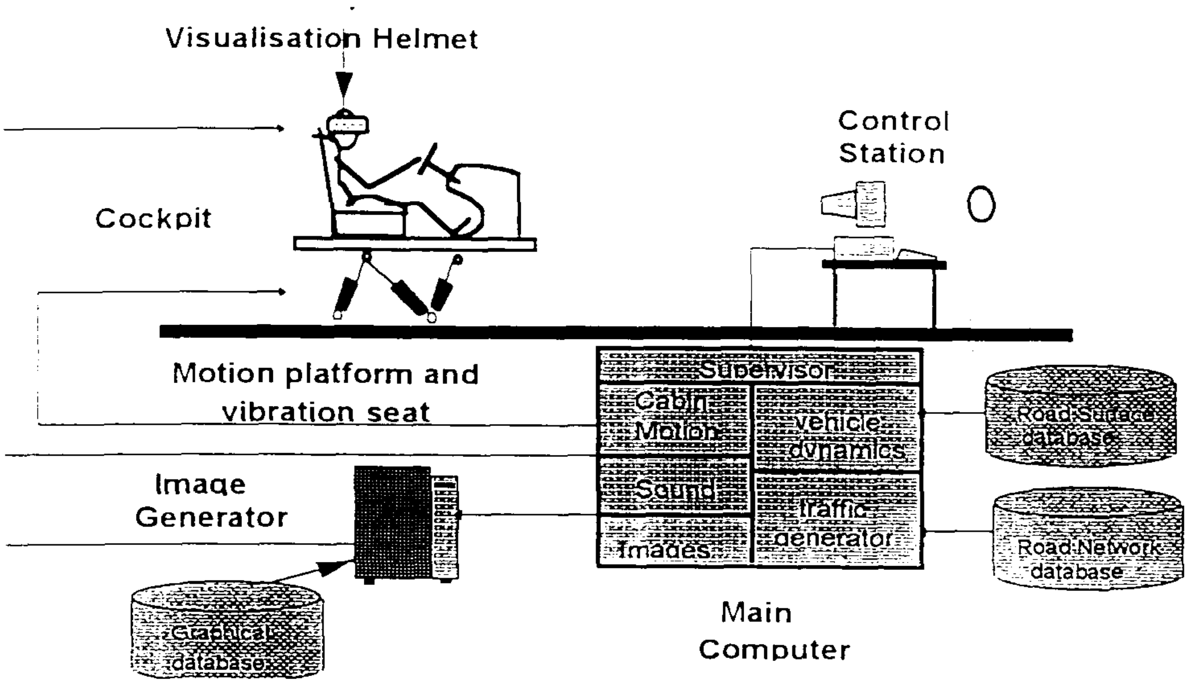

Figure 8: Comprehensive Automobile Research and Development Simulator system

Such a combination of features would be very difficult, if not impossible, to achieve with projected OTW displays. However, there are two fundamental reasons why HMDs have not been widely accepted for training:

1) In the real world, drivers do not need to wear headgear.
2) Visual performance of HMD-based systems to date has not been adequate, particularly with regard to transport delay [7], compensation for head movement and field of view. Furthermore, optical limitations (resulting in eyestrain or sickness) and discomfort (mass, centre of gravity, hygiene etc.) have also been widely quoted as being significant problems.

The large field of view HMD under development by SEOS for the CaRDS project will address all of the problems relating to performance and, as a result, it is believed that a highly successful research system will result. The first problem remains, nonetheless, and whether or not wide user acceptance in driver training could be achieved is an open question.

A new class of display?

By addressing the important attributes and limitations of currently available OTW display systems, we could derive a list of characteristics that we would like to see on a car or truck simulator. Ideally, we would like it to offer: -

- Low cost
- Close image distance on the driver's side

- Longer image distance elsewhere
- Continuous image of high contrast and luminance
- Low maintenance
- Light weight
- Re-use of the design to eliminate one-time costs
- Flexibility to change simulator cabs

Such a display is being developed by SEOS under another Eureka project, ULTIMATE.. Indeed, the concept of the project, being conducted collaboratively between Fokker Control Systems and SEOS Displays, is to provide a highly integrated motion and display platform with well-defined interfaces [8]. Thus, with little or no specific interface design, a simulator cab could be built into such an "off-the-shelf" platform in an accelerated time frame and at minimised cost. [Furthermore, the motion system is specially designed for the ground-vehicle application, optimising the dynamic characteristics, rather than adopting what was in fact developed for flight simulation].

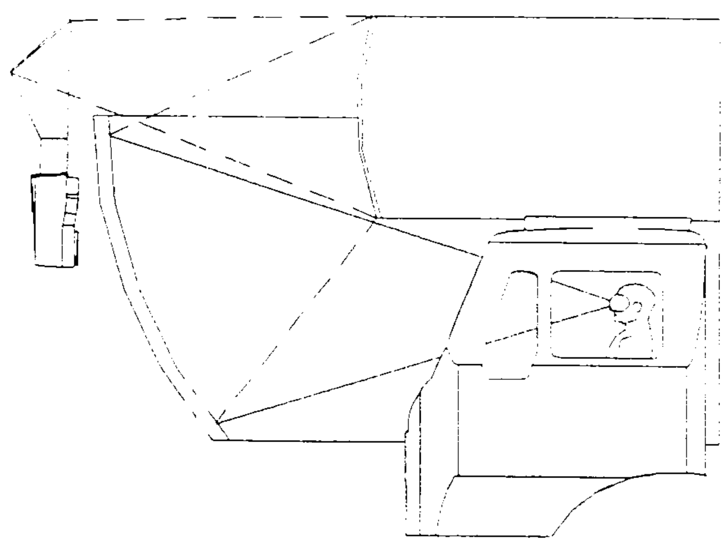

Figure 9: Front-projected PANORAMA side view

The display arrangement could be described as a "front-projected PANORAMA" (Figures 9 & 10). Instead of projecting onto a rear-projection screen from within its volume, the projectors are arrayed *outside* a screen of approximately the same dimension, firing radially inboard onto a front-projection surface. The screen is now significantly less expensive, whilst the projectors themselves can be of LCD or other low-maintenance fixed-matrix type. This arrangement presents three problems to solve, each of which has a solution under development:

1) Focus   the reverse screen curvature is not the intended application for the off-the-shelf lenses typically found on projectors. However, novel techniques will solve this problem at low cost.
2) Distortion – again, the reverse screen curvature creates a problem, this time in the form of a pincushion distortion to the projected channel images. The SEOS *Mercator* distortion

correction system will eliminate this problem by applying a bi-linear digital re-mapping function to the image.

3) Edge blending – an optical blending system will provide a fully seamless multi-channel image across the field of view.

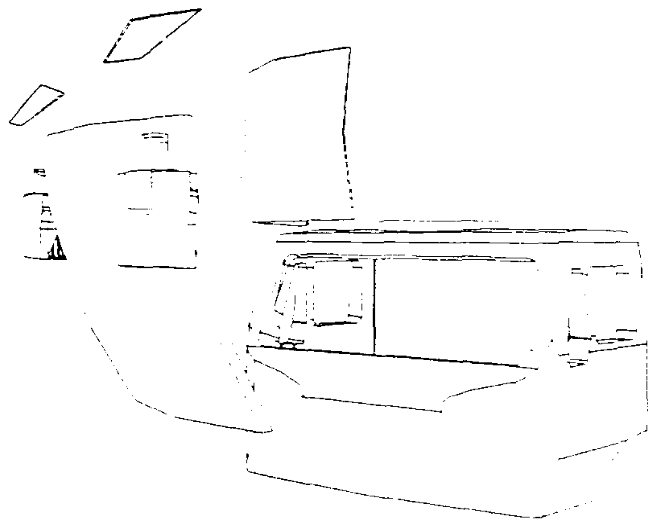

Figure 10: Cut-Away Perspective

The combination of a number of enabling techniques results in a novel display system[2] that exhibits all of the key characteristics listed above as desirable. These techniques are:

→ The front-projection layout, which places the projectors outside the enclosed display volume. This releases a large open space into which a wide variety of simulator cab types could be introduced. The only special interfacing required would be to ensure that the design eye height is correct so, if the basic layout was to allow for the largest cab, then everything from a car to an airliner cockpit could be introduced. An added benefit is that the projection system could be entirely maintained from the outside of the main simulator.

→ Special screen shape – we are no longer constrained by the specialist manufacturing techniques of translucent rear-projection screens. The front-projection screen can be made from low-cost materials and furthermore may be of any required shape. As described earlier, the image distance in a tilted collimator is dictated by the relationship between the screen and mirror curvatures. Therefore, if the shape and or position of the screen are specially adapted, it is possible to design for a short image distance on the driver's side and to have this distance increase in the straight-ahead and kerb-side directions. Figure 11 illustrates this principle, where the screen shape has been adapted to give this effect. There are many shapes that could be chosen, from spherical (where the relative offset to the mirror axis is shifted to reduce the image distance on the driver's side) to a complex aspheric shape. Simple shapes like cylinders may also be acceptable, although the variation in image distance will be more extreme, particularly in the vertical direction. Another application that would benefit from such variation in image distance

[2] Patents have been applied for

is that of in-flight refuelling simulation, where the fuel boom that appears to the edge of the pilot's field of regard should appear to be just a few metres away.

→ Use of LCD or other fixed-matrix projectors - which are light in weight and optically stable. Also, the relatively high f-number of the optics allows a far greater flexibility in optical design to solve the focus and distortion problems.

→ For additional resolution, the ability to readily stack small fixed-matrix projectors of this type can be exploited to give very high resolution. Instead of a single projector at each location shown in figures 9 and 10, two (or more) could be stacked, whilst the spacing between locations could be reduced. An example system would then comprise 12 projectors, in pairs of 2, covering 180° x 45° to give a basic display resolution of approximately 2.7 arc-min/olp from 1280x1024 projectors. Either low-cost PC Image Generator channels would then provide the content, or a smaller number of Image Generator channels in combination with a pixel sharing system could be used.

→ Digital distortion correction system – introduced between the Image Generator source and the projectors, with which the pincushion distortion is removed. (see Appendix). Such distortion could be performed within the Image Generator, but cost and or additional transport delay would be incurred.

→ Optical blending – to ensure that adjacent overlapped channels are blended fully, including the residual black-level component that cannot be modulated within the video path.

Table 2 gives a flavour for the type of performance achievable:

PARAMETER	SPEC	COMMENT
Field of View	Up to 220° x 45°	9-foot or 10-foot mirror radius
Resolution	1024-line or 1280-line	6 or 5 arc-min/optical line pair (olp) display
Luminance	>10 Ft-Lamberts	Conservative value
Contrast	>15:1	
Blend uniformity	<2%	Variation through blend region
Number of channels	3 or 5	For 180° x 40°
Mass	Approx 1000kg	All-up load on motion base. Further reduction may be possible.
Cost		For repeat systems
Motion compatibility	Normal simulation standards	
Maintenance	Colour balance once per month. Lamp changes twice per year	Both to reduce in frequency as lamp performance improves

Table 2: Predicted performance of the new display system.

As indicated, there may be the need for five display channels to provide sufficient resolution. Indeed, special arrangements are possible to provide super-high resolution with larger channel counts [5]. As PC platforms appear to be becoming the Image Generators of choice,

the cost impact of the additional channel count is unlikely to be a major consideration. Most importantly, by standardising on a single design and exploiting low-cost components, a display which provides virtually all desirable attributes can now be affordable.

Conclusions

Depending upon the simulator application, there are a number of options available for OTW displays. Each current solution offers its own specific benefits, but also shows a limitation in one or more of a number of areas, be it motion compatibility, scene continuity, cost, image distance etc. A new class of display is proposed which, while avoiding the main performance drawbacks, would appear to meet cost expectations, at least for specialist users and many research applications. Novel design and standardisation across a wide range of vehicle types achieve this, which could ultimately result in cost-effectiveness for general training.

Additional Figures:

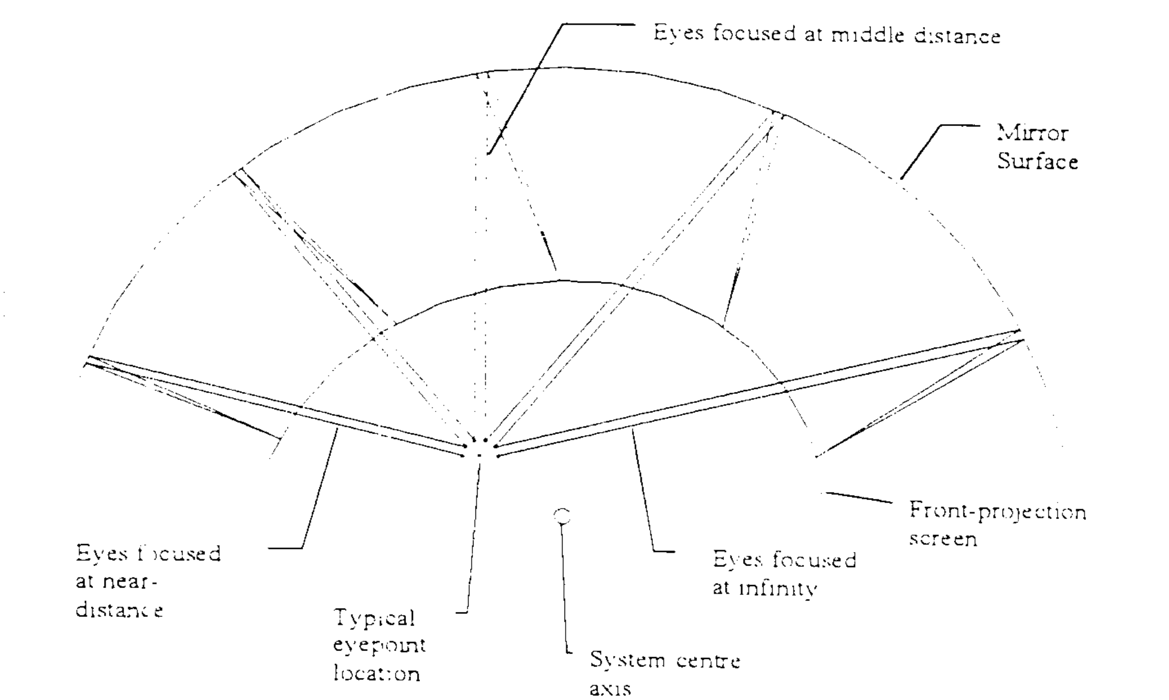

Fig. 11: Plan view of collimation system showing image distance reduced to the driver's side and increasing image distance towards the opposite side of the field.

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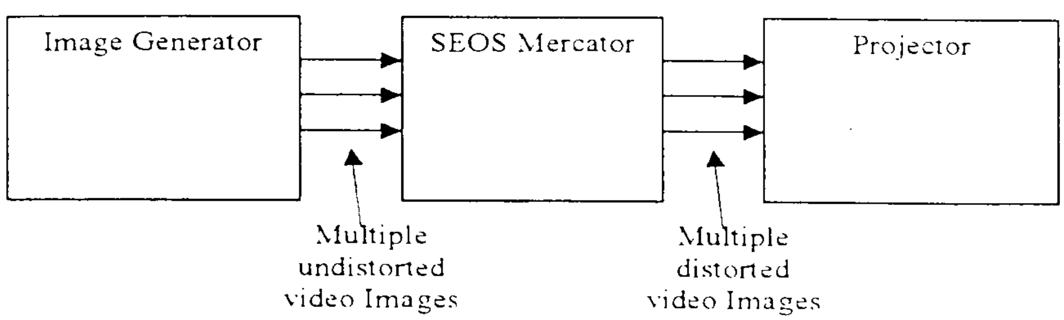
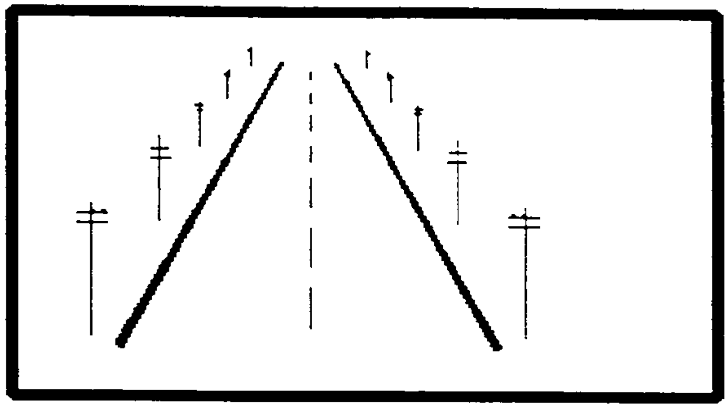
APPENDIX: Digital Distortion Correction

The SEOS Mercator is designed to correctly change the geometry of a video image in order to map that image onto a curved screen so that it appears correctly shaped. Traditionally, the mapping from rectangular image to curved screen has been implemented in CRT projectors which have the ability to "bend" the picture using magnetic fields acting on the electron beam. Other technologies such as LCD and DMD have become much more popular but the image is physically a rectangle and is hence unable to be shaped to match the curved screen. In order to do this, the image itself can be pre-distorted.

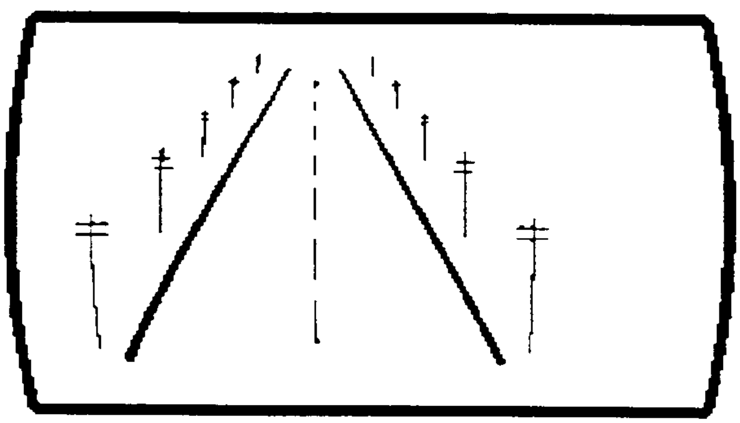
The Mercator unit takes in the undistorted image from an image source, distorts that image according to a predefined algorithm, then the image is sent to the projector. The distortion algorithm is configurable, taking in such data as projector position, eyepoint position and producing a near approximation to the ideal distortion. This can then be interactively tuned to take care of any non-predictable distortions.

The distortion will be applied using bilinear interpolation, where each output pixel is generated from the appropriate weightings of the four nearest input pixels. This method, although superior to one that uses no filtering techniques, can still result in a resolution loss or other image artefacts, generally proportional to the amount of distortion being applied. These artefacts will be minimised by the use of anti-aliased imagery.





Pre-distorted image



Distorted Image